

POTENTIOMETRIC SURFACE MAP AND WATER-LEVEL TRENDS IN THE UPPER YELLOWSTONE RIVER VALLEY, PARK COUNTY, MONTANA



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Front photo: Armstrong Spring Creek at the north end of the Paradise Valley. Photo by Sara Edinberg, MBMG.

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PLATE

Plate 1 is available online at the publication website.

Figure P1. Potentiometric surface map.
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PREFACE

This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Atlas for the Park and Sweetgrass County groundwater characterization study (GWCP09). It is intended to stand alone and describe the potentiometric surface and representative hydrographs for the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Park–Sweetgrass Area, the reader is referred to the other publications in the Montana Ground Water Assessment Atlas 9 series.

This map intends to give the user a regional overview of groundwater occurrence and elevation, and aid with initial conceptual models for large-scale investigations. Because the map generalizes sparse data and simplifies local hydraulic gradients, this product may not accurately represent site-specific heads or the presence or absence of actual artesian flow at individual well locations. Readers seeking site-specific interpretations should assess groundwater elevation contours to determine whether the density and distribution of data points in the area of interest are sufficient to support a more refined contour interval.

INTRODUCTION

This map presents the potentiometric surface of the basin-fill and bedrock aquifers of the Paradise Valley, Montana (plate 1, fig. P1), and groundwater hydrographs from water levels measured throughout the Upper Yellowstone River Valley. The Paradise Valley is located in Park County, Montana, and spans the section of the Upper Yellowstone River from Carter's Bridge (south of Livingston, Montana), to Yankee Jim Canyon (fig. 1). The Gardiner Basin consists of the valley from south of Yankee Jim Canyon to the entrance of Yellowstone National Park; this area is not represented in the potentiometric surface map because of limited data, but select hydrographs from wells in this area are used to discuss water-level patterns. Together, the Paradise Valley and the Gardiner Basin constitute the Upper Yellowstone River Valley in Montana (fig. 1).

The Upper Yellowstone River Valley is an intermontane basin bounded by the Absaroka Range to the east, and the Gallatin Range to the west (Kendy and Tresh, 1996). Basin-fill deposits consist of unconsolidated to semi-consolidated Quaternary-age alluvial and glacial deposits that make up the primary aquifers supplying the majority of wells in the valley (Edinberg, 2024). Sedimentary and crystalline bedrock aquifers are utilized in the foothills of the Absaroka and Gallatin Ranges (fig. 2; plate 1, figs. P2, P3; Lopez and Reiten, 2003; Berg and others, 1999, 2000; Crowley and others, 2017). On a regional scale, the basin-fill and bedrock aquifers act as a single

hydrogeologic unit, but on a localized scale, groundwater flows through fractures and faults in bedrock on the valley margins into the more permeable basin-fill deposits.

MAP CONSTRUCTION

This map is based on 121 static water levels (appendix A, table A1) measured by MBMG Ground Water Assessment Program (GWAP) staff. Hydrographs are based on multiple static water levels from 15 wells and one spring. Three wells were equipped with pressure transducers set to capture hourly readings. Long-term hydrographs are compiled from measurements collected from the GWAP statewide long-term monitoring network, which is comprised of about 830 wells across Montana that represent the State's major aquifers. Surface-water stage measurements for the Yellowstone River were downloaded from the U.S. Geological Survey (USGS) Water Data for the Nation database (USGS, 2026). For the potentiometric surface contours, water levels that were used were collected during the late summer (August to early September). Many of these water levels (49 wells) were measured during GWCP09 fieldwork (2013–2016); however, supplemental water levels from 72 wells measured by Olson and others (MBMG, 2005) were also used. Available hydrographs indicate that some water levels in the map area fluctuate as much as 50 ft throughout the year; therefore, it was important that water-level data used for contouring were from similar times of year. Because precipitation patterns vary annually, use of data across multiple years introduces some error;

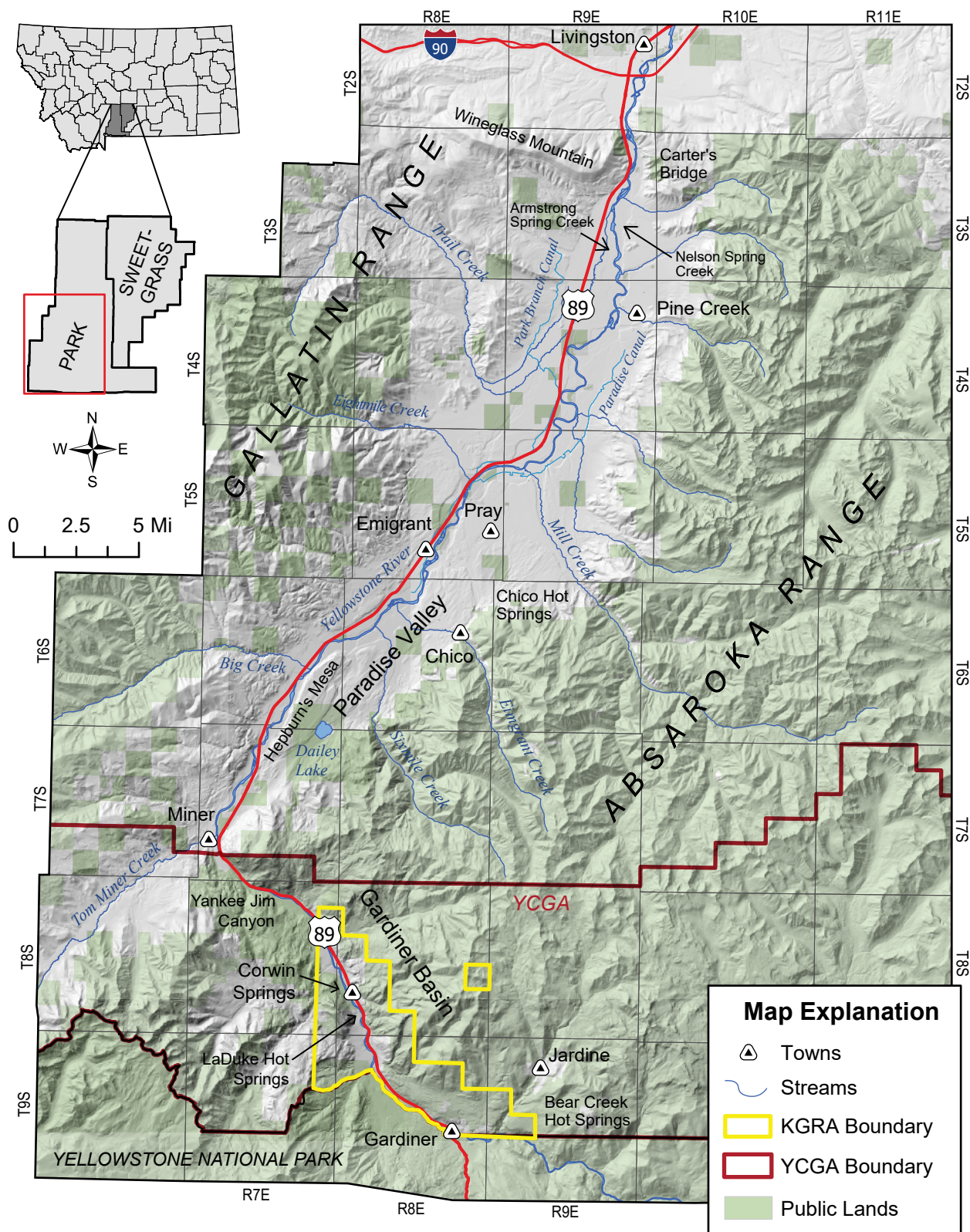


Figure 1. The study area is located in south-central Montana, along the northern border of Yellowstone National Park. The Upper Yellowstone River Valley consists of the Paradise Valley, which trends NE–SW from Carter’s Bridge to Yankee Jim Canyon, and the Gardiner Basin, which trends NW–SE and runs from Yankee Jim Canyon to the Yellowstone National Park border. Notable landmarks referenced in this publication are shown on this figure. YCGA, Yellowstone Controlled Groundwater Area; KGRA, Known Geothermal Resource Area.

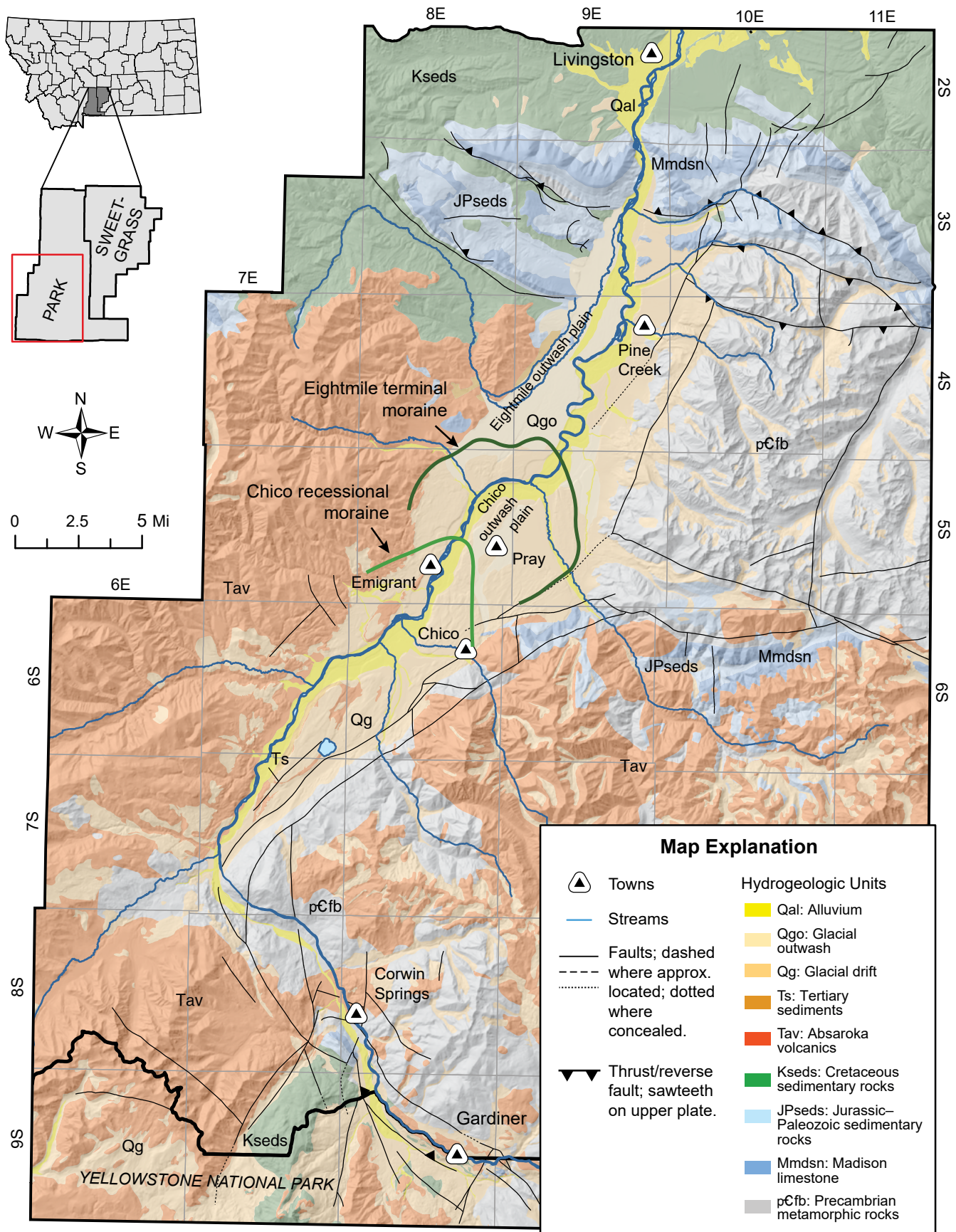


Figure 2. The geology of the Upper Yellowstone River Valley is complex due to the wide range of rock types, significant thrust faulting at the north end of the valley, and extensional (normal) faulting along the valley margins (Vuke and others, 2007). Significant glacial features are shown (Licciardi and Pierce, 2018).

however, this map is meant to represent a general interpretation of regional groundwater flow and therefore this error is considered negligible.

Water-level measurements and other site information for this map are presented in the tables in appendix A. Complete water-level data are available from MBMG's Ground Water Information Center (GWIC) database, <https://mbmggwic.mtech.edu> (GWIC, 2026)

POTENTIOMETRIC SURFACE

A potentiometric surface represents the elevation to which water in a system would rise if unrestricted; for an unconfined aquifer, it is equal to the water table. In this map, the potentiometric surface is represented by a series of contours that connect points of equal groundwater-level elevation, which can be used to infer depth to groundwater and groundwater flow direction. Flow direction is generally perpendicular to the contours, and flows from high elevation to low elevation.

The potentiometric surface map (plate 1, fig. P1) shows that groundwater generally flows from the high-elevation mountain ranges (recharge area) into the valley toward the Yellowstone River (discharge area). The basin-fill deposits have varying lithology throughout the valley due to multiple episodes of glaciation, and therefore water-bearing zones within these deposits may have limited connection on a local scale, but still share a regional flow regime.

HYDROGRAPHS

Groundwater hydrographs are presented for 15 wells and one spring throughout the Upper Yellowstone River Valley, and are developed from multiple static water-level measurements. Three of these wells were equipped with pressure transducers set to capture hourly readings.

Groundwater levels fluctuate seasonally due to variations in recharge and discharge sources. In the Upper Yellowstone River Valley, sources of recharge include precipitation (primarily snowmelt), stream loss to groundwater, irrigation practices, and leakage from irrigation canals (fig. 3). Sources of discharge include groundwater movement to surface water, and withdrawals from wells; however, large capacity irrigation wells are not a significant source of groundwater withdrawals in the study area. Well statistics from

GWIC indicate that there are just 63 irrigation wells in the valley; USGS groundwater use statistics (Dieter and others, 2018) show that irrigation makes up 15% of the total groundwater withdrawals for all of Park County (fig. 4).

When recharge exceeds discharge, water levels increase. Conversely, when discharge exceeds recharge, water levels decrease. Most of the recharge enters the basin-fill aquifers close to the valley margins, where mountain streams, including Sixmile Creek, Emigrant Creek, Big Creek, Pine Creek, and Mill Creek, lose most of their flow into the basin-fill, and where groundwater from mountain block recharge flows from fractured bedrock in the mountains into the basin-fill sediments in the valley (MBMG, 2005). Much of the recharge that enters the basin-fill aquifer discharges to the Yellowstone River. Monthly precipitation records for Park County (WestMap, 2026, Abatzoglou, 2013; plate 1, fig. P4) compared to 30-yr county averages show lower than average precipitation (rain and snowpack) during 2013, 2017, 2021, and the first quarter of 2022, and above average precipitation from 2022 to 2025. Significant declining patterns in groundwater are generally not observed in the aquifers of the Paradise Valley, but water levels in wells 99837 and 211240 (plate 1, fig. P7) are representative of a climate and precipitation response, and show a slight decline over the past several years.

Alluvial Aquifer

The alluvial aquifer was deposited by modern Yellowstone River flooding and channel migration, and wells completed in this aquifer are generally shallow, unconfined, and connected to the river. Water-level fluctuations in these wells (i.e., GWIC ID 103644, total depth 72 ft; plate 1, fig. P5) tend to reflect seasonal surface-water patterns. Although groundwater levels were only measured quarterly in well 103644, in general peak groundwater levels occur in early- to mid-June and quickly drop after high-flow conditions cease in mid- to late July.

Surface-water measurements were beyond the scope of field data collection for this project; however, USGS records indicate that the river gains water between the USGS gaging stations (Corwin Springs station USGS-06191500 to the south and Carter's Bridge station USGS-06192500 to the north; plate 1, figs. P5, P7). Synoptic stream gaging performed during the MBMG's 319 study in 2000–2005 (MBMG,

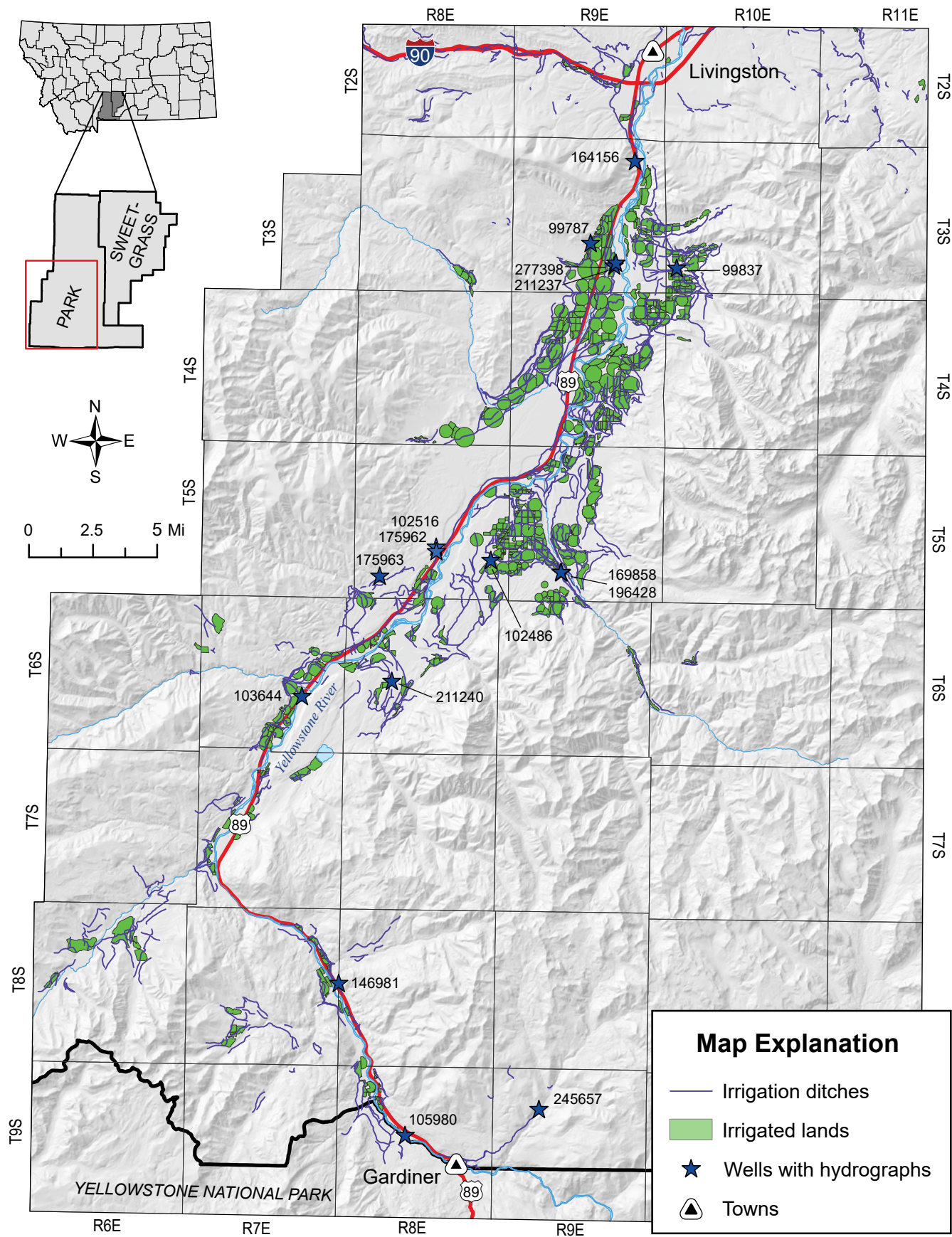


Figure 3. The Paradise Valley has a vast network of irrigation canals and irrigated fields that contribute to groundwater recharge in the basin-fill aquifers. The irrigation canals were mapped from Montana DNRC's Water Resources Survey (DNRC, 1951) and may not be an accurate representation of current irrigation structures.

Groundwater Withdrawals for Park County, Mgal/d

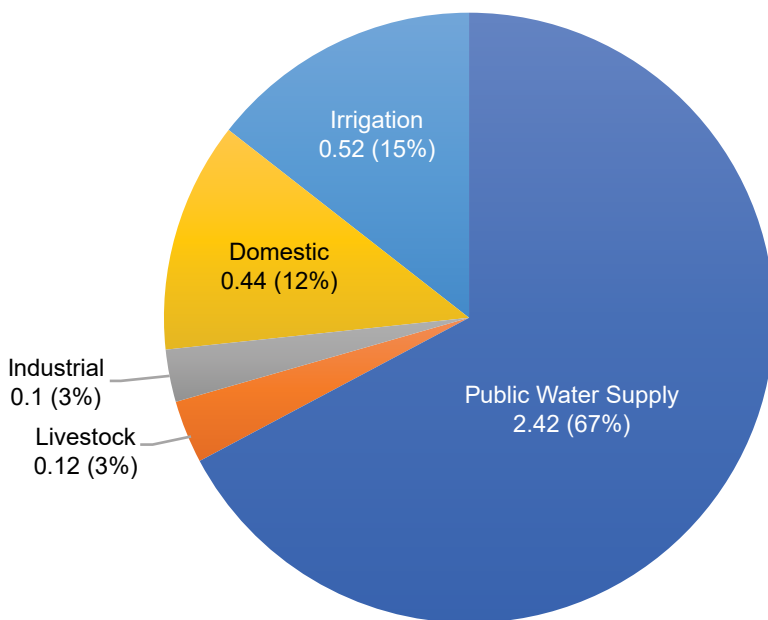


Figure 4. Statistics for groundwater withdrawals in Park County, in million gallons per day (Mgal/d). Irrigation makes up just 15% of total groundwater withdrawals in the county; the largest use of groundwater is for public water supply (Dieter and others, 2018).

2005) measured discharge at two additional stations on the Yellowstone River within the Paradise Valley (Mill Creek and Pine Creek; fig. 5). These measurements confirmed that the river is overall gaining, but showed that the reach between Mill Creek and Pine Creek loses water (fig. 5; MBMG, 2005; appendix A). Water levels in alluvial wells along the Yellowstone River near Pray indicate potential recharge to the basin-fill aquifer system from the river.

North of Pine Creek, the valley narrows and bedrock becomes increasingly shallower, creating a “pinch point” near the bedrock canyon south of Carter’s Bridge (plate 1, fig. P2, fig. P1 for location). The subsequent northward thinning of the alluvial aquifer forces groundwater to the surface, which is shown by the presence of several large spring creeks that discharge to the Yellowstone River at the north end of the valley (Clarke, 1991; Locke and others, 1995). Hydrographs from Armstrong Spring Creek and a nearby alluvial well (GWIC IDs 277398 and 211237 respectively; plate 1, fig. P6) show less than 5 ft of fluctuation throughout the year. The well and spring also have peak water levels and flows that persist through the summer and into early fall, indicating recharge from upgradient irrigation practices (canal leakage and

water applied to irrigated fields in excess of plant uptake; fig. 3). Irrigation influence sustains groundwater levels for the duration of the irrigation season (typically late May through early September), and maintains similar water levels from year to year regardless of climate fluctuations.

Glacial Deposits

For the purposes of this study, glacial deposits in the Upper Yellowstone River Valley are categorized as glacial outwash or glacial drift. Water levels, hydrographs, and recharge patterns in glacial deposits vary depending on the location, thickness, and lithology of the deposit.

Glacial outwash from the Eightmile Creek glacial advance, which occurred about 17.9k years ago (Licciardi and Pierce, 2018; Pierce, 1979; fig. 2), consists of sands and gravels deposited from a melting glacier in front of or behind the glacier’s edge. The glacial outwash forms a productive sand and gravel aquifer in the northwest portion of the valley. Like the alluvial aquifer, the outwash thins to the north, and groundwater elevations increase with closer proximity to the valley “pinch point” (plate 1, fig. P2). The glacial outwash is hydrologically connected to the alluvium, and the hydrograph from well GWIC ID 99787 (plate 1, fig. P6) shows influence from irrigation recharge (similar to well 211237), evidenced by peak water levels that extend through the fall irrigation season. This well is located just below the Park Branch irrigation canal, which likely contributes a significant amount of recharge to the outwash aquifer.

Glacial till, glaciofluvial alluvial fans, and some Pleistocene-age terrace deposits of the Yellowstone River are grouped into a general “glacial drift” aquifer. The alluvial fan deposits are present where small streams exit the mountains into the valley; during the Pleistocene, these drainages were occupied by mountain glaciers, and the alluvial fans represent deposits from these glacial or periglacial environments (Locke and others, 1995). The hydrograph for GWIC ID 99837 (plate 1, fig. P7) shows a response to seasonal runoff, with peak water levels occurring in early July. This well shows a slight decrease in peak seasonal water levels over the past several years, but maintains consistent seasonal low water levels (plate 1, fig. P4).

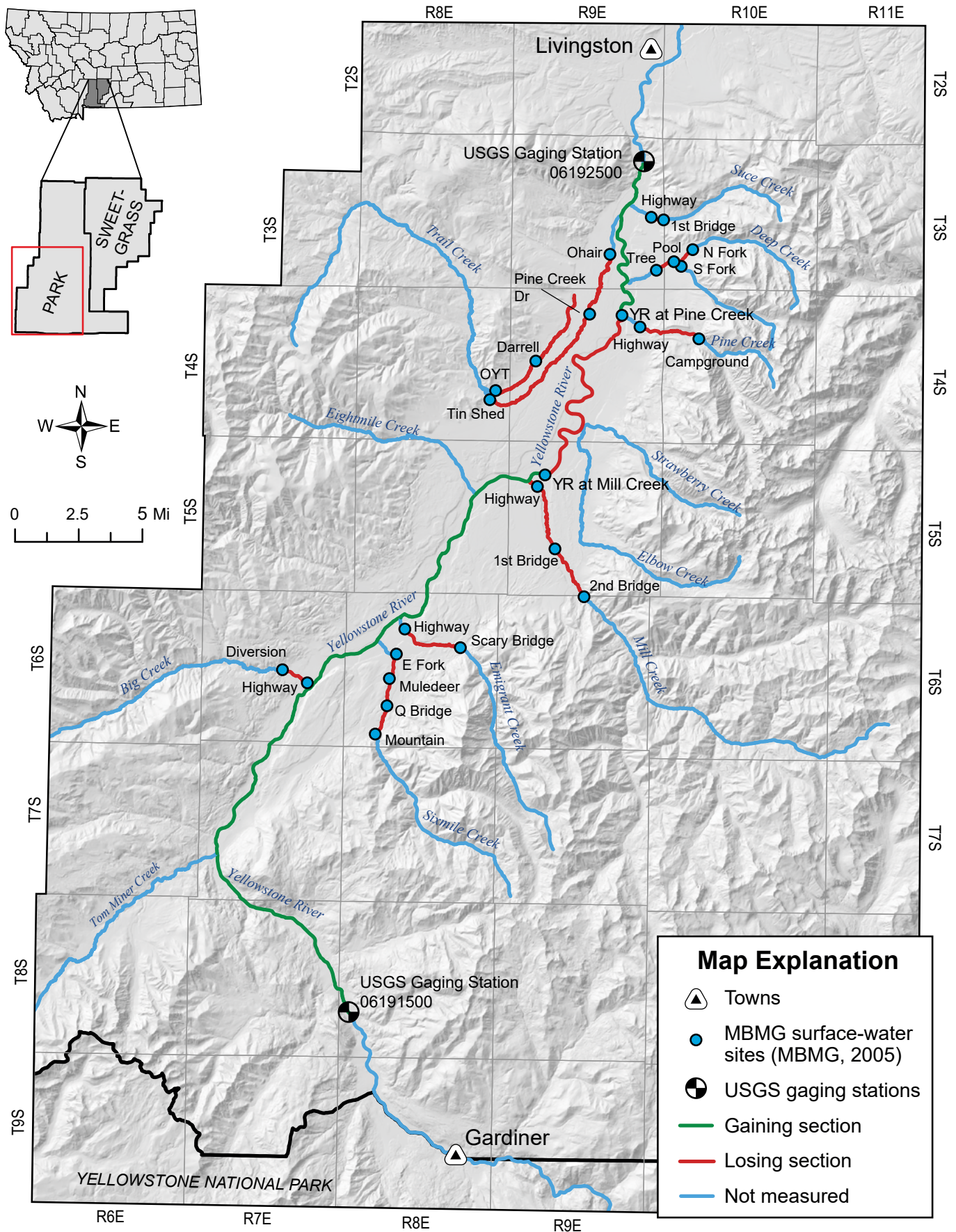


Figure 5. Sections of gaining and losing streams in the Paradise Valley, as measured by Olson (MBMG, 2005). All of the mountain streams lose flow upon entering the valley and act as a source of recharge to the basin-fill aquifers. The Upper Yellowstone is overall a gaining river, but loses water to the alluvial aquifer between Mill Creek and Pine Creek.

Well 211240 is also completed in glacial deposits and shows a similar water-level pattern.

Glacial till is the most widespread of the basin-fill deposits. The Eightmile terminal moraine represents the maximum extent of Pinedale glaciation in the Paradise Valley; Eightmile-age till extends from the moraine south to about Pray (fig. 2). The Chico recessional moraine is less distinctive, but Chico-age till (approximately 17.1k years old) is present from Pray to the south end of the Paradise Valley at Miner (fig. 2; Licciardi and Pierce, 2018). Till lithology primarily consists of claybound gravels with discontinuous lenses of sand and gravel. Most wells are completed in these sand and gravel lenses, and although they are locally disconnected, the potentiometric surface map indicates connection on a regional scale. The claybound gravels likely have a lower transmissivity, which delays recharge to deeper sand and gravel intervals from surface-water infiltration and irrigation practices (where present). This is especially evident in the Mill Creek area, where hydrographs are available from a set of paired wells (fig. 6).

Well 196426 is 116 ft deep and is completed in the shallower alluvium of Mill Creek. This well shows typical seasonal recharge patterns, with water levels peaking in June (fig. 6) and essentially going dry from late winter through late spring. Well 169858 is 480 ft deep and is completed in claybound gravels of the Eightmile till. Seasonal groundwater levels peak in November (fig. 6). Well 102486, completed at a depth of 220 ft and located further down Mill Creek, shows a similar pattern, with water levels peaking in December or early January (plate 1, fig. P8). The difference in peak water levels demonstrates a delay in seasonal recharge to the deeper sand and gravel intervals in the Eightmile till; this recharge “pulse” was originally observed by Olson (MBMG, 2005), who calculated groundwater travel times of about 130 ft/d in the till/fan aquifer. Because the shallow alluvial aquifer in the Mill Creek area does not appear to be sustainable year-round, the potentiometric surface map was drawn using water levels from the deeper glacial drift aquifer. This created a slight difference from Olson’s potentiometric surface map (MBMG, 2005), which contoured the potentiometric surface using the shallow alluvial well on Mill Creek.

Till from the Chico glacial episode appears to be thinner than the Eightmile till, based on lithology logs

from wells completed in the Chico till. Water-level trends in the Chico till show more typical seasonal recharge patterns (GWIC ID 211240; fig. P7), without the recharge delay seen in the deeper Eightmile till wells. This is likely because wells in the Chico till are generally shallower than those in the Eightmile till, and therefore have shorter recharge pathways. Well 211240 does not show influence from irrigation recharge.

Igneous and Metamorphic Bedrock

The majority of wells in the Upper Yellowstone River Valley are completed in basin-fill deposits; however, a growing number of wells (18%) are drilled in fractured bedrock. These wells are mostly located along the valley margins. Most fractured bedrock wells are completed in the igneous rocks of the Absaroka volcanics; only a few wells are completed in the Precambrian granitic and metasedimentary rocks, and these wells are primarily in the Gardiner Basin area. The smaller number of bedrock wells means fewer data points are available from these aquifers.

West of Emigrant, hydrographs are available from several wells completed in Absaroka volcanics (GWIC IDs 175963, 175962, 102516, and 146981; fig. 7). These hydrographs show little variation throughout the year (less than 1 ft in some cases), and do not seem to respond to seasonal recharge events. This may partly be due to the locations of these wells; all are located upgradient of surface water and irrigation features (plate 1, fig. P1; fig. 3). Water-level elevations in the Absaroka volcanics generally fit those of nearby basin-fill wells, indicating some connection between the volcanic and basin-fill aquifers.

The only hydrograph available for a well in the Precambrian bedrock is in the Gardiner Basin (GWIC ID 245657; fig. 8). This well shows little fluctuation, and water levels appear to be independent of precipitation patterns.

Sedimentary Rock

Only 7% of wells in the Upper Yellowstone River Valley are completed in sedimentary rock aquifers, and therefore data from these aquifers is limited. The Cretaceous sedimentary rock aquifer has one hydrograph available from a well near Gardiner (GWIC ID 105980, total depth 263 ft; plate 1, fig. P5); this well is located near the Yellowstone River, and water levels appear to reflect precipitation (snowmelt) patterns and subsequent river levels.

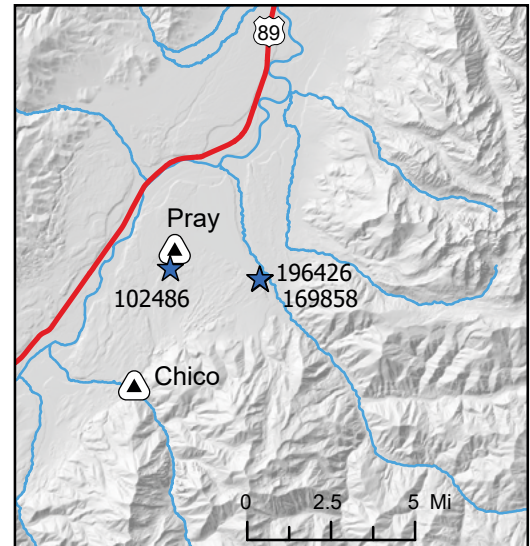
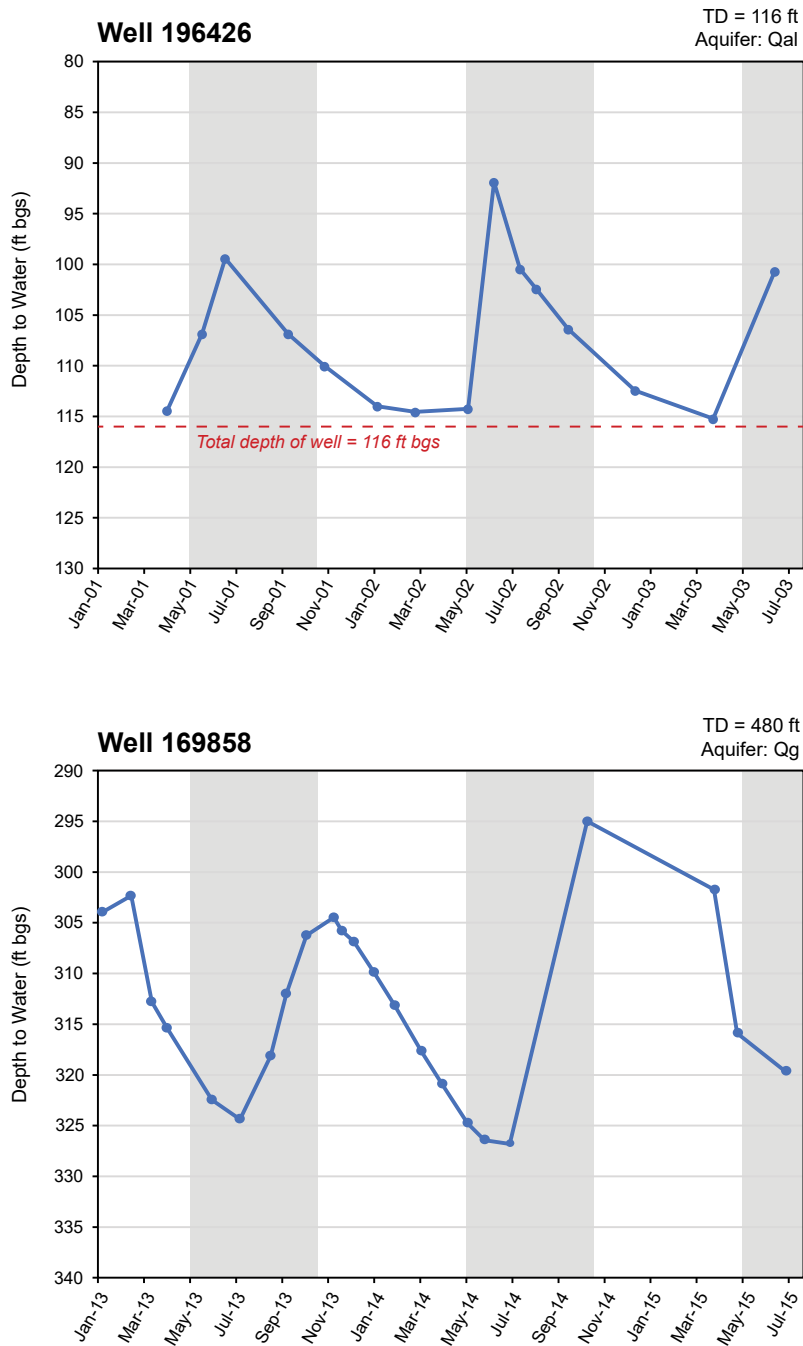


Figure 6. Hydrographs for two wells located along Mill Creek. Well 196426 is completed in the shallow alluvium of Mill Creek; well 169858 is completed in deeper glacial till. The gray bars show the approximate window of irrigation ditch operation in the valley (DNRC StAGE data, 2026). These wells demonstrate how the claybound gravels of the glacial till delay movement of recharge from precipitation and surface water to groundwater in the Mill Creek area. The shallow alluvial well has peak water levels in late June, and does not show influence from irrigation; recharge to this well is likely from surface water losses from Mill Creek, and this well appears to go dry in the winter and early spring. The deep glacial drift well has peak water levels during the winter due to the delay in mountain front recharge; a similar pattern is seen at well 102486 (plate 1, fig. P8).

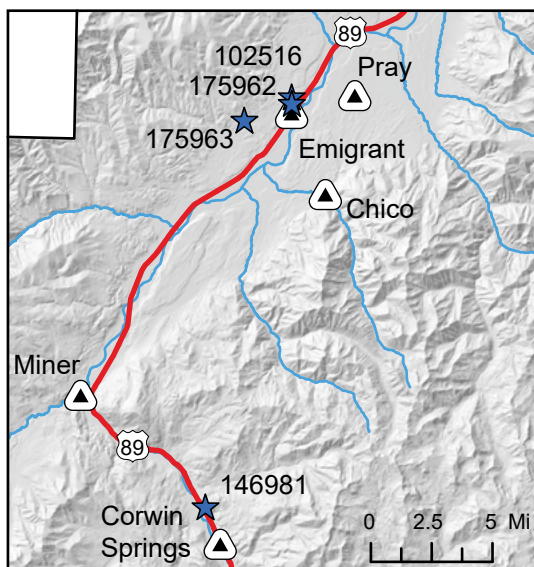
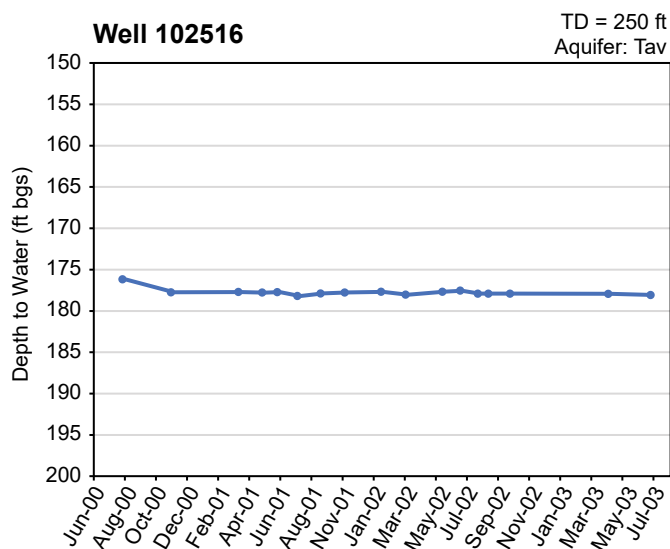
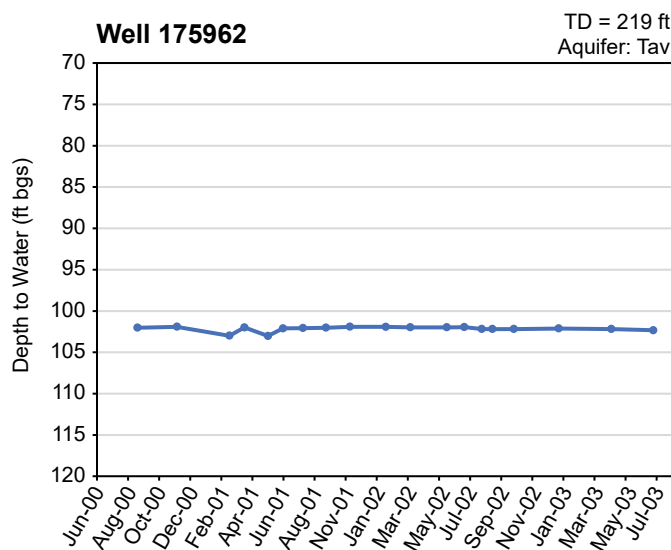
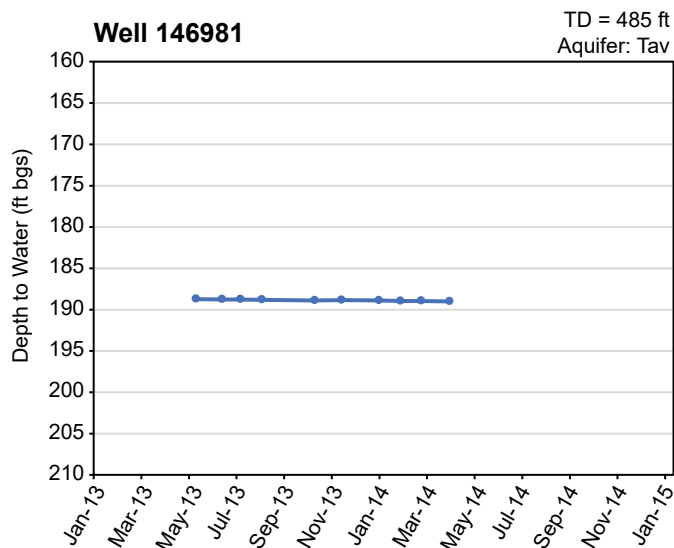
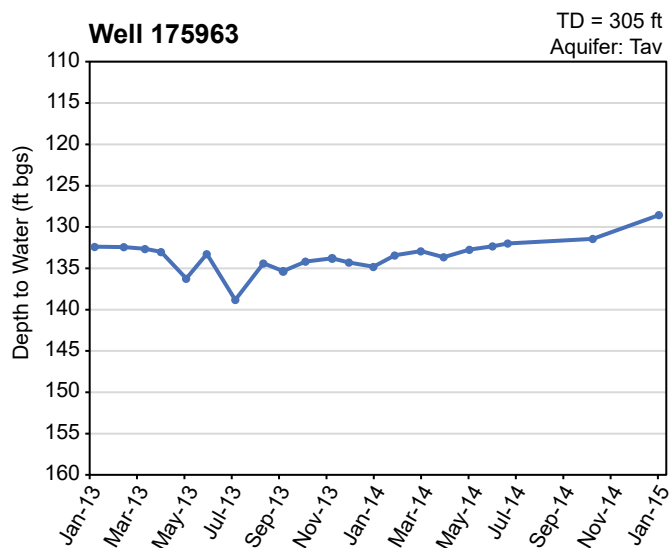


Figure 7. Wells completed in the Absaroka volcanics show little variation in water levels over time. Irrigation structures (canals, pivots, etc.) are primarily located in the valley bottom or along valley margins, downgradient of wells in the Absaroka volcanics. This aquifer is not influenced by irrigation practices, and the lack of variation in monthly water levels suggests minimal seasonal recharge from precipitation.

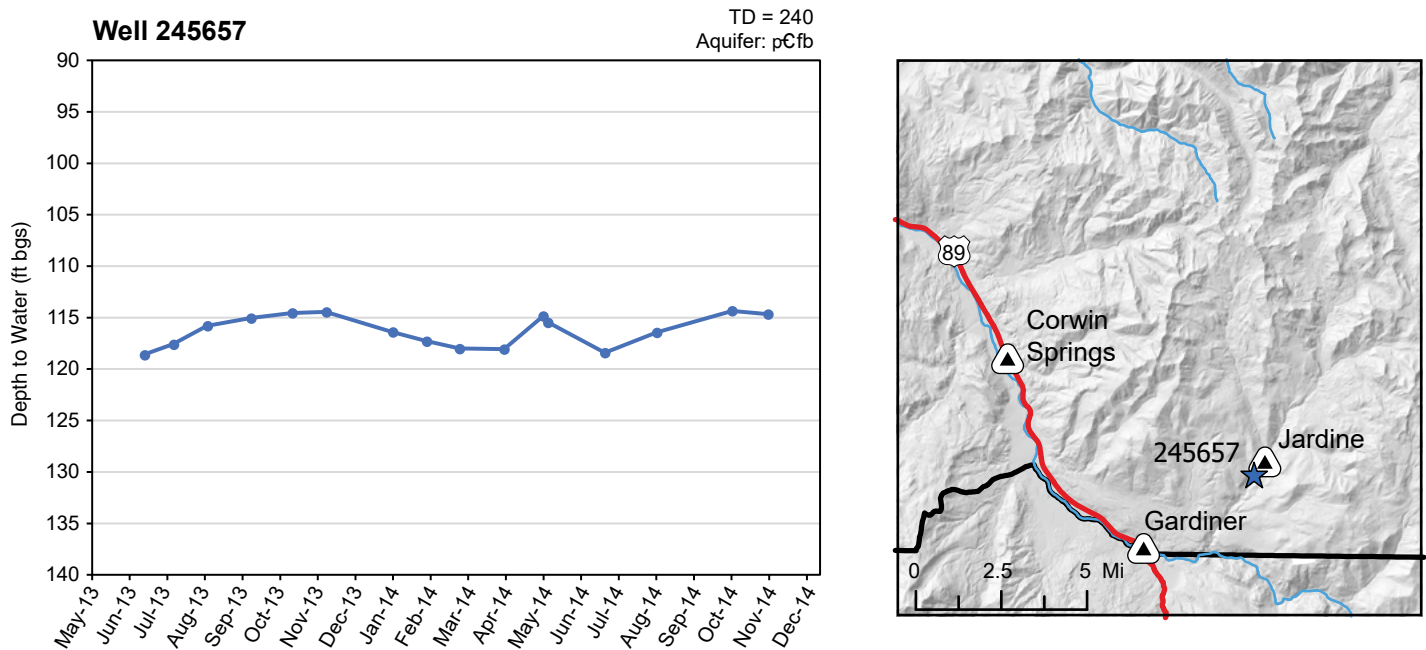


Figure 8. Similar to the Absaroka volcanics, the Precambrian metamorphic bedrock shows little fluctuation in water levels throughout the year. This formation is only utilized as an aquifer in the Gardiner Basin; therefore, available water-level data is limited.

Wells completed in the Madison limestone are present where the Madison outcrops, both at the valley margins and on the valley floor. Madison wells on the valley floor have water-level elevations that fit the potentiometric surface of the basin-fill, so it is likely that the Madison and basin-fill aquifers are connected in these areas. Long-term water levels are available for one well completed in the Madison (GWIC ID 164156; plate 1, fig. P7); this well is located in the narrow bedrock canyon at the north end of the valley near Carter's Bridge. Water levels in this well show a seasonal recharge pattern, with peak elevations in June that quickly drop once the spring runoff ceases.

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